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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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MISSOURI HEADWATERS BASIN
HILL RESERVOIR DAM
MADISON COUNTY, MONTANA
MT-899

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THREE CREEKS WATER COMPANY
(OWNER/OPERATOR)

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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the Corps of Engineers and the State of Montana Department of Natural Resources and Conservation, Hill Dam was inspected by Hoskins-Western-Sonderegger, Inc., on September 18, 1979, under the authority of Public Law 92-367. Hill Dam is located in Madison County, Montana, approximately 10 miles northeast of Sheridan, Montana.

This report was compiled from information obtained during an on-site inspection, a review of operation records, and analysis of hydrologic and hydraulic data. Findings were compared to engineering criteria currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

Hill Reservoir, located in Beaverhead National Forest, has been operated through a special use permit issued by the Forest Service for irrigation storage. However, the storage of water is currently not permitted by the Forest Service due to the poor condition of the dam. The reservoir has a drainage area of 1.35 square miles, a surface area of about 10 acres at the spillway crest, and storage at dam crest of about 60 acre-feet. In accordance with the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), the 17-foot-high (hydraulic height) Hill Dam (MT-899) is classified as small in size.

The dam is located such that its failure could endanger approximately 8 inhabitable structures located approximately 8 miles below the dam, as well as some cropland, irrigation facilities, and possibly a secondary road. No dam breach analysis or routing of a dam breach flood was made for the downstream area. The conclusions on probable damage are based on a brief field visit and on engineering judgment. The project is classified as having a high (Category 1) downstream hazard potential.

Inspection criteria (Ref. 1) recommend that a small-sized project with a high downstream hazard potential be capable of safely handling a flood in the range of one-half the probable maximum flood (PMF) to the PMF. The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Considering the number of inhabitable structures within the flood path and the distance from the dam site of about 8 miles, we recommend that the project safely handle one-half the PMF.

During the dam safety analysis, an estimated PMF was developed for the drainage basin. The PMF resulting from a generalized 72-hour storm has an estimated volume of approximately 1255 acre-feet. The reservoir level at the beginning of the 72-hour storm was assumed to be at the irrigation outlet invert elevation. Routing of the estimated PMF indicates that the dam will overtop when approximately 9% of the PMF volume enters the reservoir.

The dam is constructed of materials that will erode and fail when overtopped by flood waters. On the basis of the field inspection and the study of hydrologic and operational data, Hill Dam does not conform to Corps guidelines with resepct to discharge and/or storage capacity to safely handle the recommended spillway design flood. This inability could lead to loss of life and property.

Seepage was found at the downstream toe, in the vicinity of the conduit outlet, even though no water was impounded in the reservoir. Evidence of seepage was found near the downstream toe for almost the entire length of the embankment. No piezometers are installed to measure water levels in the embankment and there is no known internal drainage system. The downstream slope of the embankment is considerably steeper than that normally found to be adequate for similar structures. The irrigation outlet works were found to be in poor condition and appear to have deteriorated beyond reasonable repair. The large amount of debris in the reservoir and spillway channel was also found to be a serious deficiency. Conditions described in this report suggest that the dam does not conform to criteria in the recommended guidelines (Ref. 1) with respect to the stability of the downstream slope.

RECOMMENDATIONS

A downstream warning plan, for use in the event of possible embankment failure, needs to be developed and placed into operation immediately. Extensive rehabilitation is necessary if water is ever again to be stored in the reservoir. Remove all trees, brush, and root systems from the embankment and spillway channel and eliminate rodent populations in the same areas. Properly backfill resulting depressions and repair rodent damage. The conduit inlet structure, the trash rack, and the access walkway to the gate control all need to be repaired or replaced. Inspect the full length of the conduit and repair or replace, as needed. A formal maintenance program and a program of periodic safety inspections at no more than 5-year intervals need to be established.

Conduct more-detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity and modify the project as the studies indicate. Engineering studies, including field investigations, piezometer installation, and laboratory testing and analysis, are required to determine whether the embankment requires modification to provide stability in conformance with the recommended guidelines. If there is no further need for impounding water, a sufficient portion of the embankment should be removed, in a safe manner, to prevent impounding hazardous volumes of water.

Prior to performing engineering studies and remedial construction, coordinate the work with the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

Stephen H. Nickel
Professional Engineer

17 x .5 x 10 = 85 AF

PERTINENT DATA

1. GENERAL

Federal I.D. No.	MT-899
Owner	Three Creeks Water Company
Operator	Three Creeks Water Company
Date Constructed	Prior to 1916
Purpose	Irrigation
Location	Sec. 25 & 26, T3S, R4W
County, State	Madison County, Montana
Watershed	Indian Creek (North Fork)
Downstream Hazard Potential	High (Category 1)
USGS Quadrangle	Waterloo, Montana

2. RESERVOIR

Surface Area (Spillway Crest)	10 acres
Storage (Spillway Crest)	45 acre-feet
Total Storage (Minimum Dam Crest)	60 acre-feet
Surcharge Storage	15 acre-feet
Drainage Area	1.35 square miles
Reservoir Water Surface Elev. (9/18/79)	8506.5 feet (NGVD)

how calculated

3. SPILLWAY

Type	Uncontrolled earth & rock channel
Crest Elevation	8519.4 feet (NGVD)
Width (Crest)	19 feet (approximate)
Length	60 feet (approximate)
Spillway Capacity (Minimum Dam Crest)	90 cfs

4. OUTLET WORKS

Type	Controlled corrugated metal pipe with trash rack at inlet
Controls	Manually operated slide gate with rising stem and access catwalk
Size	15-inch-diameter CMP
Length	101 feet
Inlet Invert	8506.3 feet (NGVD)
Outlet Invert	8505.5 feet (NGVD)
Normal Tailwater	Unknown
Discharge Capacity (Minimum Dam Crest)	12 cfs

5. DAM

Type	Earth
Hydraulic Height (Crest to Toe)	17 feet
Crest Length	630 feet
Minimum Crest Elevation	8521.5 feet (NGVD)
Crest Width	7 to 10 feet (Varies)
Upstream Slope	1(V) on 2.8(H)
Downstream Slope	1(V) on 1.5(H)

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of Hill Reservoir Dam, owned and operated by Three Creeks Water Company of Sheridan, Montana.

The National Dam Inspection Act, Public Law 92-367, dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Office of the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams", Appendix D to "Report of the Chief of Engineers on the National Program of Inspection of Dams", dated May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam;
(2) based upon an evaluation of the available data and a visual inspection;
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations, and analyses are necessary or warranted; and
(4) not intended to include extensive explorations or analysis or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the

exception of situations of extreme emergency. In these cases, the Corps may proceed with Phase II studies, but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and neither action nor failure to act under this Act shall be construed: (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act, or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on visual inspection of the project and interviews with the owners and/or individuals familiar with the dam facilities. No design drawings or foundation exploration results were available for review or analysis. However, records of infrequent inspections dating as far back as May 1916 were furnished for reference. Inspection procedures and criteria were those established by the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1).

Personnel present during the inspection included:

Louis Boitano, Civil Engineer, Seattle District Corps of Engineers; and
Art Taylor, State of Montana, Department of Natural Resources and Conservation.

Hoskins-Western-Sonderegger, Inc. (HWS) personnel who participated in the field inspection and contributed to this report are:

Stephen Nickel, Geotechnical Engineer, Team Leader;
Michael McMeekin, Hydrologist/Hydraulics Engineer; and
Gene Holtorf, Hydrologist/Hydraulics Engineer.

No representatives from either the Forest Service or Three Creeks Water Company participated in the inspection.

This report has been reviewed by representatives of the Montana Department of Natural Resources and Conservation, the U. S. Forest Service, and the Three Creeks Water Company. Their written comments are enclosed in the Appendix of this report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Hill Reservoir (MT-899), owned and operated by Three Creeks Water Company, is an onstream irrigation impoundment for water collected near the headwaters of an unnamed tributary of Indian Creek North Fork. It is located in Section 25, Township 3 South, Range 4 West, Madison County, Montana, approximately 10 miles northeast of Sheridan, Montana (see Plate 1). Although the Forest Service has prohibited the storage of water, the reservoir would have a surface area of approximately 10 acres, with storage at the minimum spillway crest (elevation 8519.4 feet) of approximately 45 acre-feet, less than 1 acre-foot of which is natural storage. The local drainage area is approximately 1.35 square miles. The uncontrolled earth and rock spillway, approximately 19 feet wide at the crest, is located on the dam about 250 feet north of the south (left) abutment. The dam has a 15-inch-diameter corrugated metal outlet pipe with a manual control gate, located roughly 60 feet south of the north (right) abutment. Hill Reservoir Dam is 17 feet high and impounds approximately 60 acre-feet at the minimum dam crest elevation of 8521.5 feet. Based on a visual reconnaissance and engineering judgment, approximately 8 homes located about 8 miles below the dam could be affected by a sudden breach of the dam. On the basis of this information and in accordance with the Recommended Guidelines (Ref. 1), this dam is classified as small in size and has a high (Category 1) downstream hazard potential.

1.2.2 Regional Geology

The Tobacco Root Mountains are bounded on the north by the Jefferson River Valley; on the east by the Madison River Valley; on the west by the Beaverhead River Valley; and on the south by the Gravelly-Greenhorn Mountain Ranges.

The Tobacco Root Mountains have an igneous batholitic intrusion as a core with older metamorphic and sedimentary rocks mantling the igneous core. Associated with igneous intrusion, but not contemporaneous, is the structural development of the mountains by block faulting and thrust faulting. Present surficial sediments have a glacial origin at higher elevations and near the valley floor, in the lower elevations, are loosely consolidated (valley-fill) sediments.

The northern Rocky Mountain region, prior to Late Cretaceous time, was essentially a flat plain partially flooded by shallow seas. At the end of the Mesozoic Era, of which the Cretaceous is the last geologic epoch, this entire area became geologically active. Three things exemplify this activity: (1) Cretaceous uplift; (2) Late Cretaceous thrust faulting; and (3)

Late Cretaceous-Tertiary intrusive activity, i.e. the Tobacco Root Batholith.

The regional uplifting of the continental crust brought the earth up in several north-south trending blocks. The west sides of the faulted blocks, or mountains, are higher in elevation and have characteristically abrupt scarps, while the east sides of the blocks have long, gentle slopes. This is typical of mountains that have formed in the geologic province called the Basin and Range Province.

1.2.3 Seismicity

Hill Dam, located on the western slope of the Tobacco Root Mountains, lies in Seismic Zone 3 as indicated by the Seismic Zone Map (Ref. 1). The seismic probability of this regional setting is one of potential for major damage and is based on the known distribution of damaging earthquakes in the region.

The Preliminary Map of Young Faults in the United States, by the U. S. Geological Survey (Ref. 2), indicates suspected activity along the northwestern expanse of the Tobacco Root Mountains during Holocene time. Major faulting has also occurred prior to the Cenozoic Era in the western and northern regions of the Pioneer Mountains according to the Montana State Geologic Map.

Epicenters of local earthquakes significant enough to be reported in References 3 and 4 occur to the north-northeast along a line from 20 miles northwest of Helena to 25 miles north of Bozeman, and to the southeast in northeast Idaho, northwest Wyoming, and the adjoining areas of Montana. Two earthquakes of significant intensity that occurred in this tri-state region were the Hebgen Lake, Montana, earthquake (8 August 1959) that had an intensity of X (Modified Mercalli) and another southeast of Dillon, Montana, and south of the project area (23 November 1947) that had an intensity of VIII. The three largest reported earthquakes northeast of the Tobacco Root Mountains have had intensities of VIII. One of these earthquakes had its epicenter at a point 25 miles north of Bozeman (27 June 1925), while the other two occurred at Helena (18 October and 31 October 1935). Of these two epicentral areas, the former is 20 to 70 miles to the south-southeast, and the latter is 40 to 75 miles to the north of the project site.

In the vicinity of the project area, there have been numerous other earthquakes in this century (Ref. 3 and 4). In an area bounded by the 44th and 46th parallels and by the 110th and the 112th meridians (including the tri-state region), there have been more than 50 earthquakes with intensities of V and more than 10 with an intensity of VI. The closest reported earthquakes to the project site have occurred near Ennis and Virginia City. The largest of these had an intensity of VI and occurred near Ennis (10 March 1977). The exact distance from the epicenter of this earthquake to the project site is not known.

The Tobacco Root Mountains lie in a high seismically active area with the potential for a damaging earthquake. This warrants special attention be given to the dams that are in the area that have been constructed without consideration given to the effects of earthquakes.

1.2.4 Site Geology

Hill Reservoir lies in a series of Precambrian metamorphic and sedimentary rocks. Numerous igneous pegatite dikes and sills of post-Cambrian age intrude these rocks. The valley is a glacial cirque with steeply sloping headwalls and gently to nearly level bottom lands. The glacial scouring is, in part, controlled by the nearly vertical dip of the Precambrian bedrock, forming the east arm of an anticline in this locality. The dam appears to have been built on a low terminal moraine which at one time impounded a small lake. The original lake is now essentially filled with sediment. Large boulders are visible along the right side of the reservoir, but it is not known whether they are part of an outcrop or are part of a lateral moraine.

1.2.5 Design and Construction History

The original dam structure at Hill Reservoir was built prior to May 6, 1916, with some reconstruction done between 1967 and 1972. A search of the files found considerable correspondence and Forest Service inspection narratives, but no plans of the original or the existing structure could be found. Visual inspection and data from Forest Service records indicate that the dam is of earth fill construction with stacked granite boulders as a core. A portion of the original irrigation outlet conduit was actually a timber-framed tunnel that extended from the downstream toe into the embankment. The tunnel was closed around 1943. The dam and associated structures have a continuous history of neglected maintenance and do not conform to Forest Service design criteria as they now exist.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway is located on the dam, approximately 250 feet north of the south (left) abutment, and discharges into an unnamed tributary of Indian Creek North Fork. The spillway is an uncontrolled earth and rock channel approximately 19 feet across the bottom and about 3.5 feet deep at the crest, with walls consisting of stacked boulders. The channel surface is generally irregular and is covered with large rocks with logs placed crosswise between the rocks (possibly for stabilization). The spillway contains a large amount of debris. Approximately 20 feet upstream of the crest, the rocky channel ends and an inoperative log boom lies deteriorating. The downstream channel remains rocky and irregular for 150 to 200 feet, until its confluence with the stream channel. The slope of the upstream channel varies from 4 percent to almost 20 percent. The downstream channel has an average slope of about 13 percent. The spillway channel is shown in Photos 11 and 12, and the profile and typical cross section are shown on Plate 4.

The spillway channel appears to be in generally good condition, with no serious erosion damage. The boulders stacked along the walls and lining the bottom of the spillway channel appear to be only marginally adequate in preventing embankment erosion damage by flows contained within the limits of the spillway channel. Under present conditions, the spillway channel would probably not be overtopped prior to the dam. Continued accumulation of debris in the channel, however, will reduce the spillway capacity and may cause overtopping of the spillway channel prior to overtopping of the dam. This could lead to serious dam embankment erosion which, in turn, may cause failure of the dam.

The excessive amount of debris, the rotting log sills in the spillway bottom, and the deterioration of the log boom are the major physical deficiencies of the spillway.

The discharge rating for the spillway was computed by assuming critical depth at the channel crest and computing water surface profiles upstream into the reservoir with Manning's "n" of 0.040. The capacity of the spillway varies from zero flow at the minimum spillway crest elevation of 8519.4 feet to a flow of 90 cubic feet per second (cfs) at the minimum dam crest elevation of 8521.5 feet. A complete discharge rating curve for the spillway is shown on Plate 6.

2.1.2 Outlet

An irrigation outlet is located approximately 60 feet south of the north (right) dam abutment. The outlet consists of a 101-foot-long, 15-inch-diameter corrugated metal pipe running through the dam. The outlet is

controlled by a vertical slide gate located at the upstream end of the pipe and operated from the top of the riser by a handwheel lift. There is a locking device on the handwheel. The wooden catwalk access to the manual control wheel is standing, but is in extremely poor condition. It is an obvious safety hazard to personnel. The slide gate is rusted and in poor condition. It has been locked open for some time to prevent the storage of water in the reservoir. The trash rack consists of rusting and bent bars, supported by the spalling and cracked concrete of the inlet structure. At the time of the inspection, the conduit inlet structure was plugged by debris and material used in forming the concrete for the inlet structure, and the conduit outlet was partially obstructed by rocks. The invert elevation of the upstream end of the pipe is 8506.3 feet, or 15.2 feet below the minimum dam crest. The invert elevation of the downstream end of the pipe is 8505.5 feet, or 16.0 feet below the minimum dam crest. The outlet invert is about 1 foot above the toe of the embankment. The irrigation outlet works are shown in Photos 7 through 9 and in Plate 2.

The general condition of the irrigation outlet is poor. As mentioned before, the slide gate and appurtenances have deteriorated beyond reasonable repair, as has the inlet structure. The visible portion of the 15-inch corrugated metal pipe was found to be rusty, but serviceable. The alignment of the pipe could not be determined.

The capacity of the irrigation outlet pipe, assuming the water level to be at the minimum dam crest elevation, was computed to be 12 cubic feet per second (cfs). This capacity was based upon full pipe flow using a Manning's "n" of 0.024 and assuming the control gate to be in the fully opened position. The complete outlet discharge rating curve can be seen on Plate 7.

2.1.3 Freeboard

Since the Forest Service has intermittently disallowed storage in Hill Reservoir for the past 10 years, the reservoir has been dry, with the exception of the small stream which meanders across the reservoir sediment.

Recent-appearing high water marks on the posts of the gate tower indicate 4- to 5-foot fluctuations during periods of high runoff when reservoir inflow exceeded the capacity of the outlet (see Photo 7). Older-looking high water marks indicate that the water surface has risen to within a few feet of the top of the dam. The vertical distance between the spillway crest and dam crest is 2.1 feet.

The effective fetch for wind-generated waves is approximately 0.13 miles. The total of wave run-up and wind set-up is approximately 1.3 feet (Ref. 5). Thus, the vertical distance between the minimum dam crest elevation and the wave height elevation (assuming water level at the crest of the spillway) is 0.8 feet. Wind waves, concurrent with spillway discharges, could overtop the embankment; however, since the dam overtops during the Probable Maximum Flood (PMF), the dam has no freeboard.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 Climatology and Physiography

The climate of the area around Hill Reservoir is continental and is characterized by large diurnal and seasonal temperature ranges. Extreme variability of wintertime temperatures results from the frequent occurrence of foehn or chinook winds which follow a Pacific maritime air mass invasion. The summers are characterized by warm days with low humidity and cool nights. Winters are moderately cold and highly variable in severity from year to year and within a given year.

Pony, in Madison County, at an elevation of 5500 feet, is the climatological station nearest the dam site, with precipitation and climatological data available for approximately 20 years. The average annual precipitation at Pony is approximately 17 inches, with over 65 percent of the precipitation falling from March through August. By contrast, at Hill Dam (elevation 8520 feet), the annual precipitation averages approximately 45 inches (Ref. 7). Also, in the area of Hill Reservoir, the average expected date of first freeze is August 28th, and the average expected date of the last freeze is June 29th (Ref. 8).

The drainage basin above and including Hill Reservoir is approximately 1.35 square miles. Other than the main stream upon which Hill Reservoir was built, there are no perennial tributaries draining into the lake. Basin elevations range from the spillway crest elevation of 8519.4 feet to approximately 10,380 feet at the drainage divide. Basin vegetation consists of moderately thick pine and sparse grasses on the lower basin area to sparse pine on extremely rocky surfaces on the upper basin area.

2.2.2 Reservoir Storage and Spillway Discharge

As stated previously, the impoundment of water in Hill Reservoir has been disallowed by the Forest Service, due to the deteriorated condition of the dam; however, should the dam be restored, the lake has a surface area of about 10 acres and a storage volume of 45 acre-feet at the spillway crest elevation of 8519.4 feet. Approximately 15 acre-feet of storage are available between this spillway crest and the minimum dam crest elevation of 8521.5 feet. Discharge through the spillway with the reservoir at the minimum dam crest is approximately 90 cubic feet per second (cfs). Discharge through the irrigation outlet under these conditions would result in an additional 12 cfs with the control gate in the fully opened position. Complete stage-area and stage-storage curves for the reservoir are shown on Plate 5. Complete discharge rating curves for the spillway and irrigation outlet are shown on Plates 6 and 7, respectively.

2.2.3 Estimated Probable Maximum Flood

The Probable Maximum Flood (PMF) is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The probable maximum precipitation

(PMP) for Hill Reservoir was derived in the following manner: the 24-hour, 12-hour, 6-hour, and 1-hour PMP depths were estimated from National Weather Service Technical Paper #38 (Ref. 9) to be 15.2 inches, 13.2 inches, 11.2 inches, and 7.1 inches, respectively. The 48-hour and 72-hour PMP depths were taken as 110 percent and 115 percent of the 24-hour PMP, or 16.7 inches and 17.4 inches, respectively. All 6-hour increments were arranged in a critical order of occurrence, using criteria presented in the U. S. Weather Bureau's Hydrometeorological Report No. 43 (Ref. 10).

The PMF was assumed to result from a PMP storm in the late spring over hard and frozen ground. Thus, a constant soil loss rate of zero was applied throughout the 72-hour storm in accordance with Corps of Engineers' recommendations. For this reason, the overall configuration of the 72-hour storm is not affected by losses in the soil, and the basin rainfall is equal to the basin runoff for all storm increments. Direct precipitation onto the surface of the reservoir was also added in, with no losses.

2.2.4 Flood Routing

The reservoir level at the beginning of the 72-hour storm was assumed to be at the irrigation outlet invert elevation of 8506.3 feet. This corresponds to the present normal pool condition with the reservoir drawn down and no storage allowed. Routing the PMF beginning with an empty reservoir indicates better performance of the project than would occur if the reservoir contained some water prior to the PMF.

The total volume of the 72-hour PMF for Hill Reservoir is approximately 1,255 acre-feet. Reservoir routings indicate that with the control gate of the irrigation outlet closed, the lake will handle approximately 9.2% of the PMF volume before overtopping. With the control gate fully open, the lake will handle approximately 9.3% of the PMF volume before overtopping. A smaller percentage of the PMF would be controlled should the present spillway become blocked with debris.

PMF hydrographs were developed using the SCS dimensionless unit hydrograph. Reservoir routings of the inflow hydrographs were made using the modified Puls method. The HEC-1 (Dam Safety Version) computer program (Ref. 11) was used for the hydrograph computations and reservoir routings.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Embankment

The 17-foot-high earth dam is 630 feet long and has a crest width which varies from 7 feet on the north end of the dam to 10 feet on the south end. The upstream slope is 1(V) to 2.8(H). The downstream slope is 1(V) to 1.5 (H). Borrow for the embankment construction appears to have been obtained from areas above both abutments and below the downstream toe. The material exposed on the surfaces of the dam is a sandy silt to silty sand, containing cobbles and boulders. The sand contains visible mica particles. This embankment material is considered to be highly erodible.

Vegetated areas of the embankment include the downstream face, the crest, and the upper 1 to 3 feet of the upstream face, of which approximately 50% is covered with weeds and grasses. Some small fir trees, generally ranging from 2 to 4 feet tall, are growing on the crest and downstream face. Portions of the upstream face have riprap of metamorphic boulders in good condition. Embankment erosion through the riprap is not apparent, although no evidence of a granular bedding or filter course was found. More than one-half of the upstream face is not protected by riprap. However, in the areas with no riprap, there is no evidence of wave erosion. There is no visual evidence of slumps or slides on either the upstream or the downstream faces of the embankment.

The crest and downstream face contain many rodent holes.

Records indicate that the embankment has a stacked boulder core. However, no evidence of this was seen, indicating that it does not extend to the crest.

2.3.2 Foundation Condition, Seepage, and Drainage

The dam is probably founded on soil similar to that used in the embankment. This material is considered to be quite pervious. Since the reservoir was empty at the time of inspection, actual seepage conditions of the embankment could not be evaluated; however, there is evidence of seepage and apparent efforts to control the effects of seepage over almost the entire length of the embankment, both on the downstream face and near the downstream toe. On both sides of the conduit outlet, there is lush, tall grass, indicating seepage either through the foundation or along the conduit (see Photo 9). Near the spillway, logs have been placed on the downstream slope in what appears to have been an attempt to stabilize the slope because of seepage. Near the left abutment, the downstream face of the dam has been covered with riprap, apparently for the same reason (see Photo 6). In this area, seepage water has formed a pond below the embankment and has carved a 1.5-foot-wide exit channel. Although the embankment crest elevation varies as much as 2.6 feet, it cannot be determined whether this is due to foundation consolidation or is the result of construction.

There is no evidence to indicate that the dam included any type of internal drainage system. There is no instrumentation, such as piezometers, installed in the dam.

2.3.3 Stability

Hill Reservoir appears to have been empty for several years, except during high runoff periods that exceeded the capacity of the outlet works. Since the reservoir was empty during inspection, seepage conditions could not be evaluated.

2.4 PROJECT OPERATION AND MAINTENANCE

2.4.1 General

Operation and maintenance of Hill Reservoir and Dam is the responsibility of the Three Creeks Water Company, with technical assistance provided by the Forest Service. Although a plan for operation and maintenance of the reservoir and dam facilities was not available at the writing of the report, Forest Service inspection reports and narratives from 1916 to 1976 infer the above responsibilities. In addition, these documents indicate a history of maintenance problems and a general neglect of reservoir and dam facilities.

2.4.2 Dam

There is no formal plan for performing periodic maintenance on Hill Dam. Inspection reports and correspondence indicate a general lack of any adequate maintenance since 1916, with the exception of some minor reconstruction which was done between 1967 and 1972.

Recent visual inspections by Forest Service personnel (1972 and 1976) found the dam in need of maintenance. Particularly mentioned were debris in the spillway and the condition of the log boom and the low-level outlet and appurtenances.

2.4.3 Reservoir

The Forest Service has disallowed the storage of water in Hill Reservoir due to the deterioration of the dam; however, recent high water marks on the gate tower catwalk indicate that the water level in the reservoir reaches approximately 4 to 5 feet above the invert of the irrigation pipe even though the gate is left open. As with the dam structure, the reservoir has no formal plan for operation and maintenance and, over the years, has received very little attention and few visits. A tremendous amount of debris, consisting mostly of fallen trees and branches, is scattered along the face of the dam embankment, shoreline, and the spillway channel.

2.4.4 Warning System

There is no formal warning system or plan of action to warn downstream inhabitants or interests in the event of impending dam failure.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of Hill Reservoir and Dam, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the following findings:

3.1.1 Size, Hazard Classification, and Safety Evaluation

In accordance with inspection guidelines, Hill Reservoir Dam is small in size and, based on our visual inspection and judgment, it has a high downstream hazard potential. Inspection guidelines recommend that for a project of this type, the spillway design flood (SDF) be in the range of 50% to 100% of the PMF. Because of the involved risk, we recommend the project handle one-half the PMF.

Based on these reconnaissance level investigations, the project controls only about 9% of the PMF volume. Because the project cannot control 50% of the PMF, it does not conform to the inspection guidelines' criteria for recommended reservoir storage and/or spillway capacity.

3.1.2 Embankment

This dam has not retained a permanent pool for several years; however, seepage was evident at the toe of the embankment near the conduit outlet. In addition, considerable seepage appears to have occurred along the entire length of the embankment when storage was permitted in the reservoir. Efforts appear to have been made to control embankment instability resulting from seepage. The apparent efforts included placing rock on the downstream slope near the left abutment and placing logs on the downstream slope right of the spillway. This work was the only repair or maintenance of the embankment or appurtenances that was readily apparent. Unrepaired rodent damage was found on the crest and downstream face. In general, the embankment and all appurtenances appear to be in poor condition.

The embankment crest is not level and varies as much as 2.6 feet in elevation. The lowest point on the crest of the dam occurs near the left abutment (see Plate 3B). This is the area where the downstream slope has been stabilized by the placement of rock.

There is no instrumentation, such as piezometers, installed in the dam.

Under the present operating conditions, with no permanent pool, the dam embankment is not subjected to steady state seepage conditions. Also, the upstream slope is not subjected to prolonged saturation which could cause instability when the reservoir is drawn down. However, even under the present operating conditions, seepage was found near the toe of the

embankment adjacent to the outlet conduit, and evidence of past seepage was found throughout the length of the embankment. Considering the seepage and evidence of past seepage, the steep downstream embankment slope (1V to 1.5 H), and experience with similar structures and embankment materials, it is our judgment that the embankment stability would not conform to Corps guidelines.

3.1.3 Spillway

The uncontrolled earth and rock channel spillway was found to be marginally adequate in preventing erosion from flows confined within channel limits. The large amount of debris in and around the spillway channel constitutes a serious deficiency. Continued accumulation of debris in the channel will reduce the spillway capacity and could cause overtopping of the spillway channel prior to overtopping of the dam. This could lead to serious dam embankment erosion which, in turn, may cause failure of the dam. The log sills running across the channel bottom at irregular intervals are rotten, which could lead to some localized erosion during high flows. The log boom, upstream from the spillway crest, is deteriorated and inoperative.

3.1.4 Outlet Works

The irrigation outlet works were found to be in poor condition. The slide gate and appurtenances appear to have deteriorated beyond reasonable repair. The gate is locked open. The inlet structure consists of cracked and spalled concrete, and the bars of the trash rack are bent and loose. The visible portion of the 15-inch corrugated metal pipe conduit appeared to be rusty, but serviceable. Its alignment and condition within the embankment could not be observed. Some seepage around the downstream end of the pipe was apparent. The wooden access catwalk to the operating controls has deteriorated to the point that it has become a serious safety hazard.

3.1.5 Spillway and Reservoir Capacity

The reservoir storage capacity and spillway discharge capacity are insufficient to prevent overtopping during the estimated PMF. This investigation has determined that during a 72-hour PMP storm, the dam can control only 9% of the PMF, if routing is started with the reservoir empty. Routings beginning with some water in the reservoir would show a less favorable performance of the project.

3.1.6 Operation and Maintenance

Operation and maintenance are the responsibility of the Three Creeks Water Company, with technical assistance provided by the Forest Service. There is no formal operation plan for the reservoir. The reservoir is not currently being used for storage. However, stream flow which exceeds the capacity of the low-level outlet is temporarily detained. In the past, the reservoir has been used for irrigation storage, being filled in the spring and having irrigation releases throughout the growing season.

There is no formal maintenance plan for the dam, and the facility has a history of inadequate maintenance. The growth of small trees on the dam, the many rodent holes, the poor condition of the outlet control works and access walkway, and the deterioration of the spillway are all indications of the lack of recent maintenance. It should be stated that access to the site is difficult. This limits possible regular maintenance to those functions which can be performed by hand. The dam is seldom visited and, for all practical purposes, has been abandoned.

There is no formal warning system or plan of action to warn downstream inhabitants in the event of impending dam failure.

3.2 RECOMMENDATIONS

The following recommendations are predicated on the project being restored to a useable, safe condition and impoundment of water for the intended purposes. If there is no further need for impounding water, the dam should be removed without delay and a safe, natural stream outlet re-established.

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam overtopping or structural failure.

2. Remove all trees, brush, and root systems from the embankment, abutments, and toe areas. Backfill and compact all resulting depressions.

3. Eliminate rodent populations and repair rodent damage.

4. Repair or replace the conduit inlet structure, the trash rack, and the access walkway to the gate controls.

5. Remove the rocks which partially block the conduit outlet.

6. Inspect the full length of the corrugated metal conduit and repair as required.

7. Remove debris from the reservoir, dam, and spillway; construct a new log boom; and remove log sills and improve spillway channel surface to protect against erosion.

8. Conduct more-detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

9. Investigate the dam foundation, abutments, and embankments; perform stability analyses and modify the embankment as required to conform to stability standards in the recommended guidelines. These studies should be performed by a qualified geotechnical engineer.

10. Develop and implement a periodic maintenance plan for the dam and appurtenant structures. The maintenance plan should include frequent condition inspections whenever water is impounded.

11. Periodic inspections of the facility should be conducted at intervals of no more than 5 years by engineers qualified in the design, construction, operation, and maintenance of earth dams.

12. Coordinate all activities with the Montana Department of Natural Resources and Conservation.

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2. Howard, K. A., et al, "Preliminary Map of Young Faults in the United States as a Guide to Possible Fault Activity", U. S. Geological Survey, Reston, Virginia, 1978.

3. U. S. Geological Survey, "Earthquake Information Bulletin", Washington D. C., 1973-1978.

4. U. S. Department of Commerce, Earthquake History of the United States, Publication 41-1, Washington D. C.

5. U. S. Army Corps of Engineers, Office of the Chief of Engineers, "Wave Run-up and Wind Set-up on Reservoir Embankments", Engineer Technical Letter No. 1110-2-221.

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7. U. S. Department of Agriculture, Soil Conservation Service, "Average Annual Precipitation in Montana", Portland, Oregon, 1977.

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9. U. S. Department of Commerce, Weather Bureau, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Technical Paper No. 38, U. S. Government Printing Office, Washington D. C., 1960.

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11. U. S. Army Corps of Engineers, Hydrological Engineering Center, Flood Hydrograph Package (HEC-1), Users Manual for Dam Safety Investigations, Davis, California, September 1978.

(PHOTO 1) Upstream Face of Dam

(PHOTO 2) Right Side of Reservoir, Showing Debris

(PHOTO 3) Right Abutment and Embankment Crest at Maximum Section

(PHOTO 4) Downstream Face of Maximum Section from Right Abutment

(PHOTO 5) Upstream Face from Left Abutment

(PHOTO 6) Downstream Face from Left Abutment

(PHOTO 7) Outlet Control Works

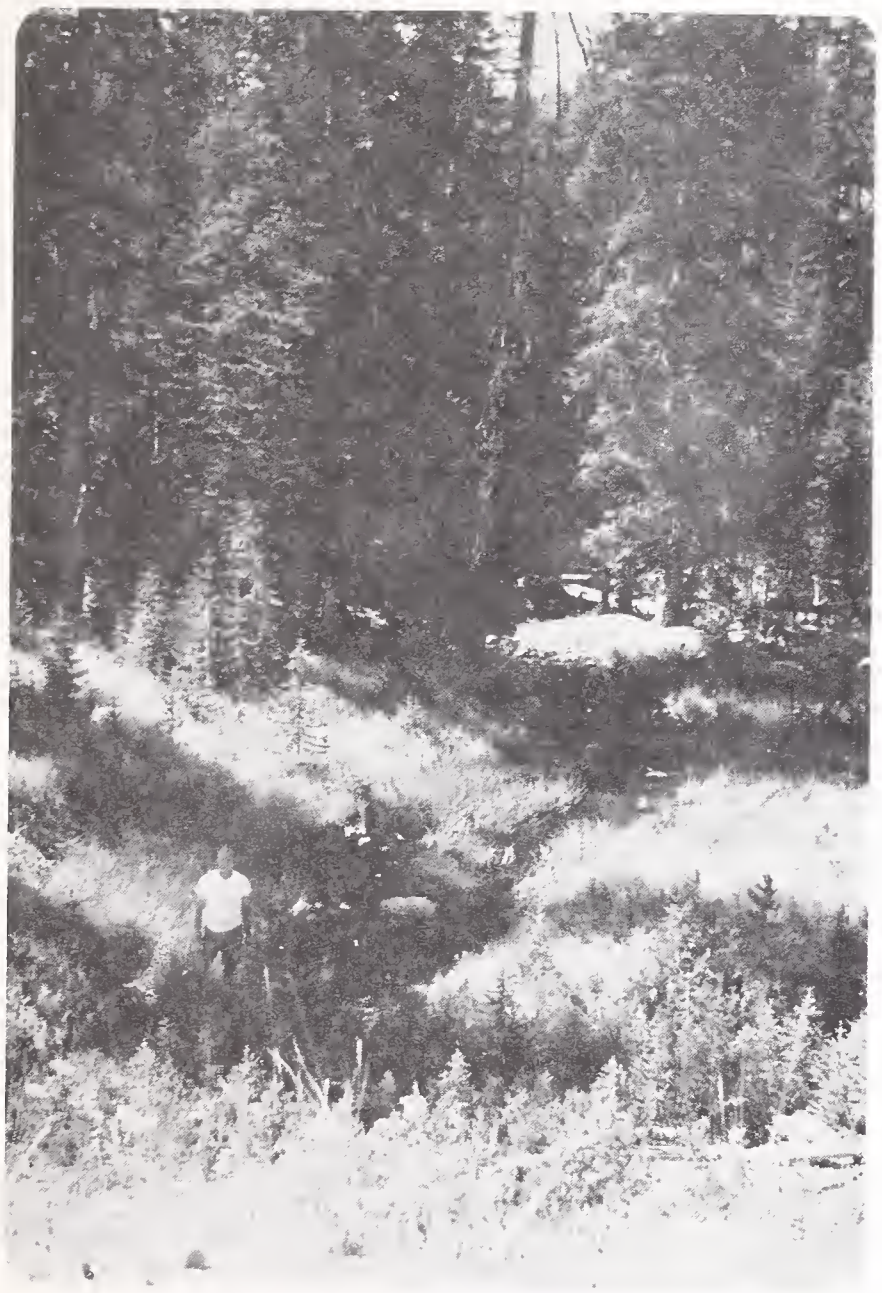
(PHOTO 8) Slide Gate and Inlet Structure

(PHOTO 9) Conduit Outlet

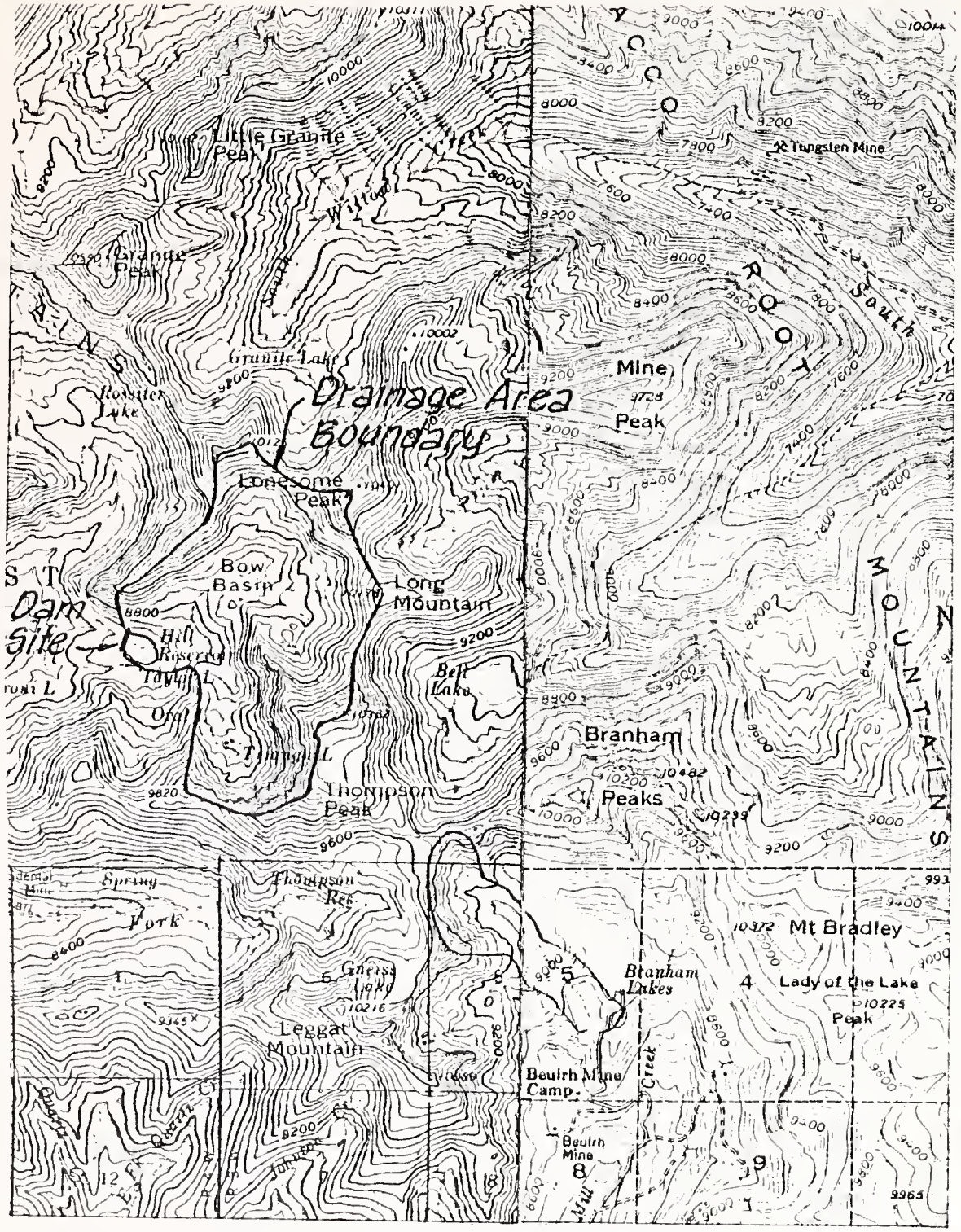
(PHOTO 10) Spillway Inlet, Log Boom, and Upstream Face of Dam

(PHOTO 11) Spillway Approach Channel

(PHOTO 12) Looking Downstream from Spillway Control Section



(PHOTO 13) Looking Downstream from Above Conduit Outlet



SITE PLAN

VICINITY MAP

PLATE 1

HILL RESERVOIR DAM
SITE PLAN & VICINITY MAP

HILL RESERVOIR DAM
DAM CROSS SECTION
@ OUTLET PIPE

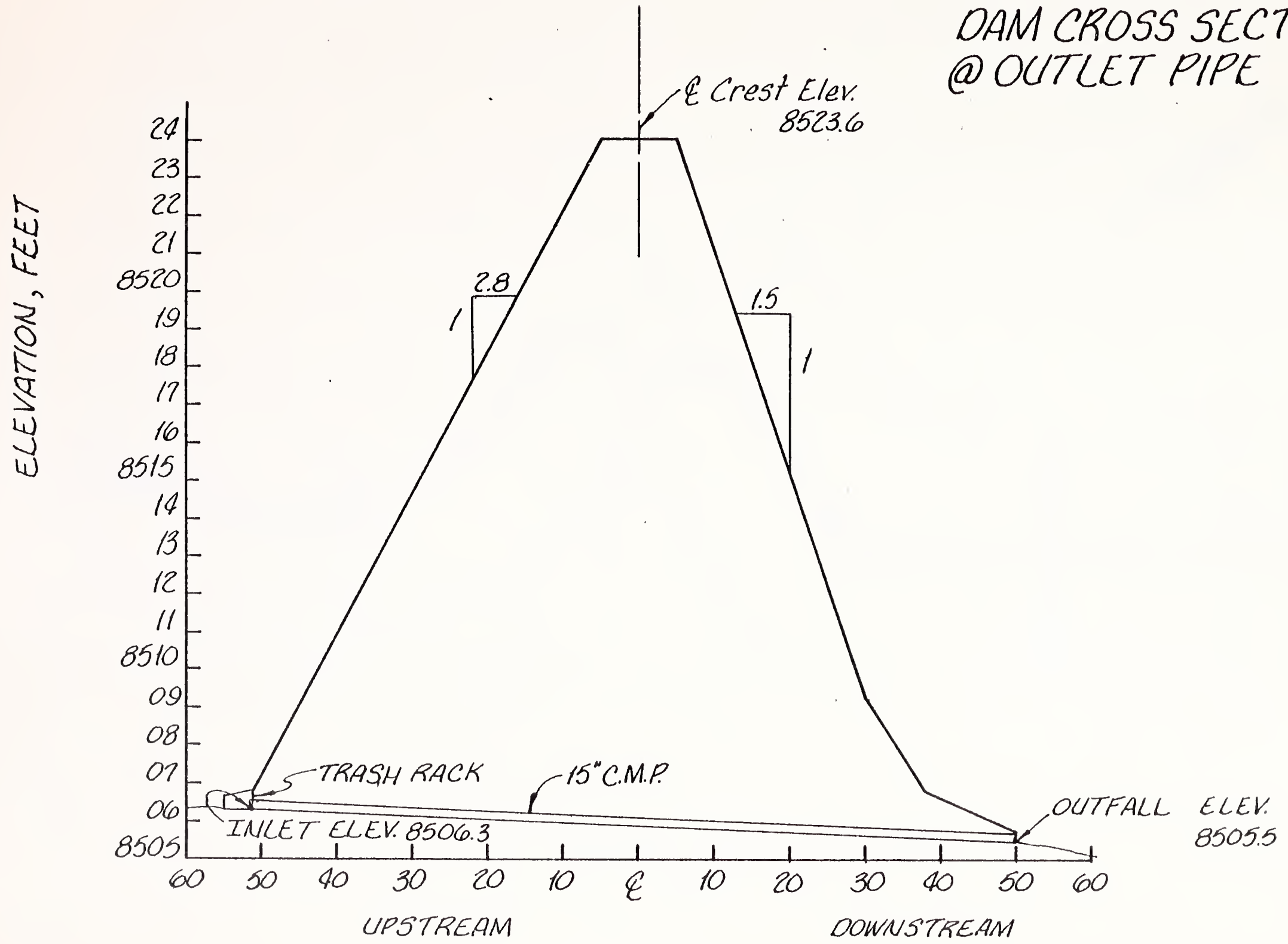
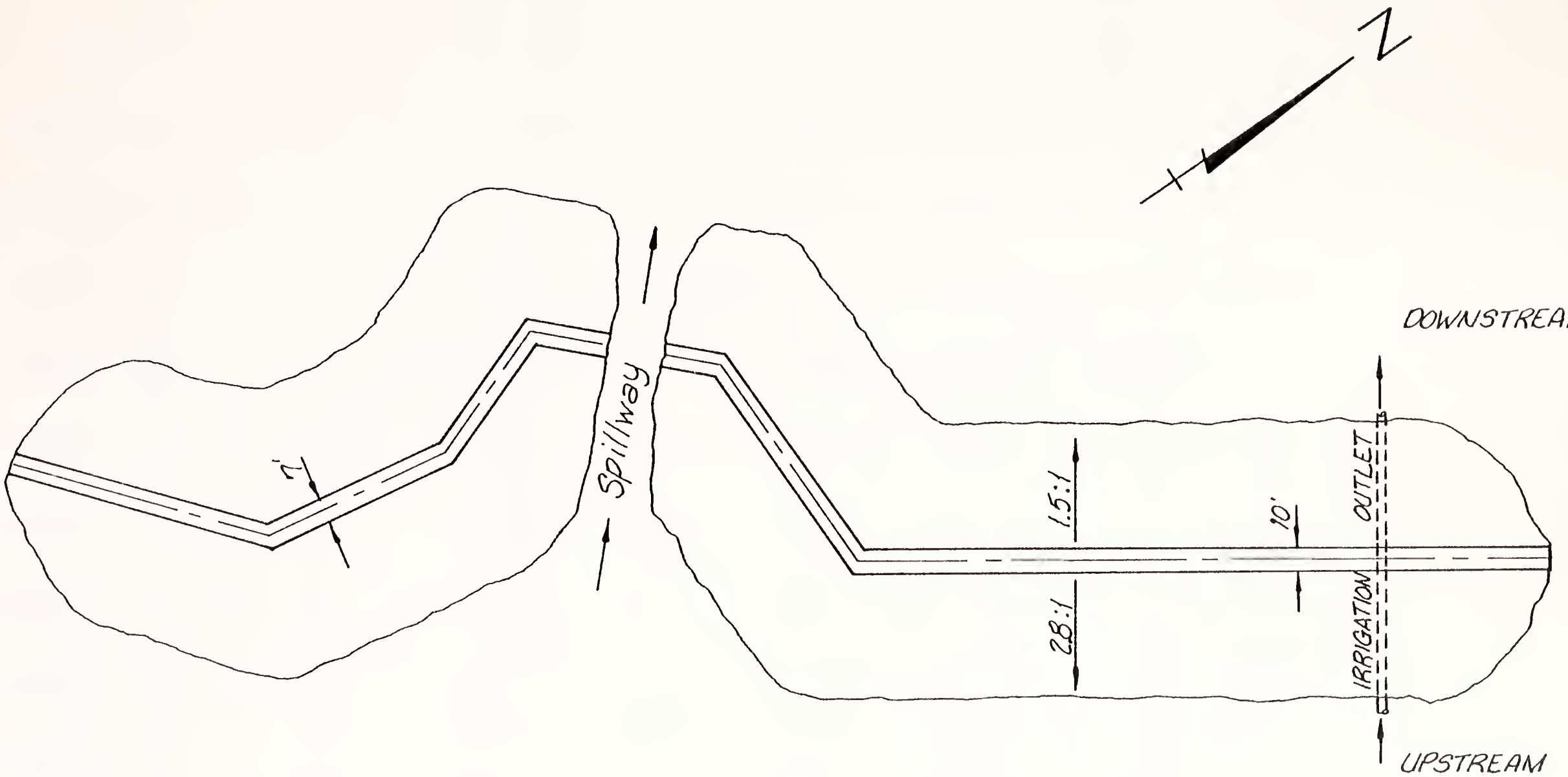


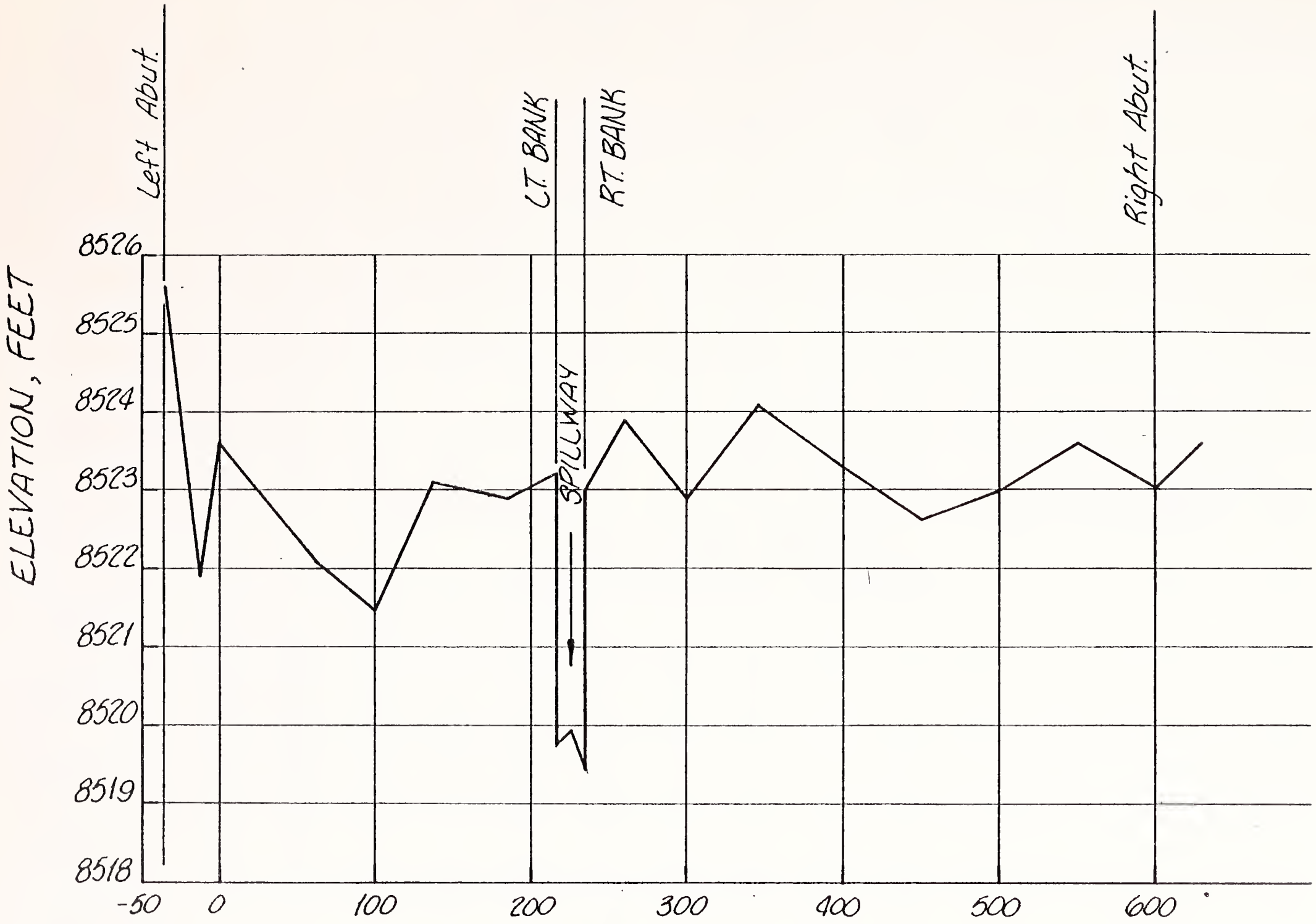
PLATE 2

HILL RESERVOIR DAM
Montana



PLAN VIEW OF DAM
Scale: 1"=60'

PLATE 3A

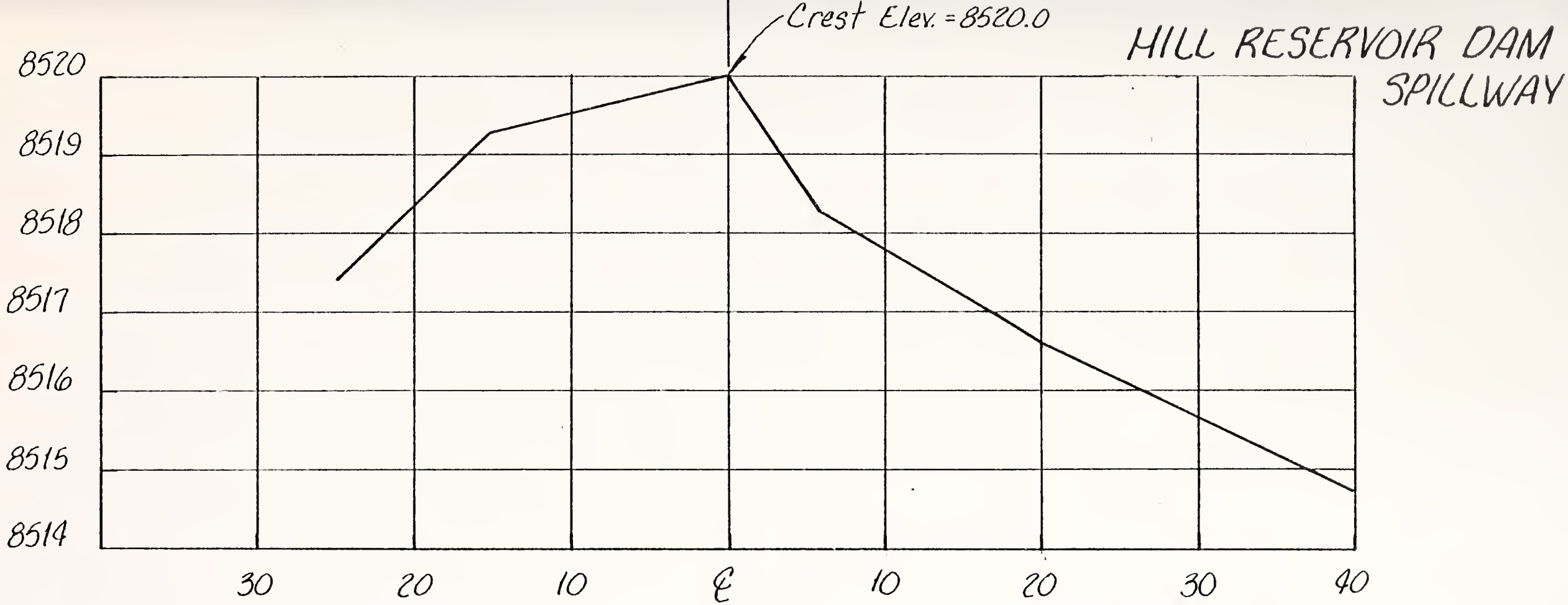


CENTERLINE DAM CREST PROFILE

Scale: 1"=100' Horiz.; 1"=2' Vert.

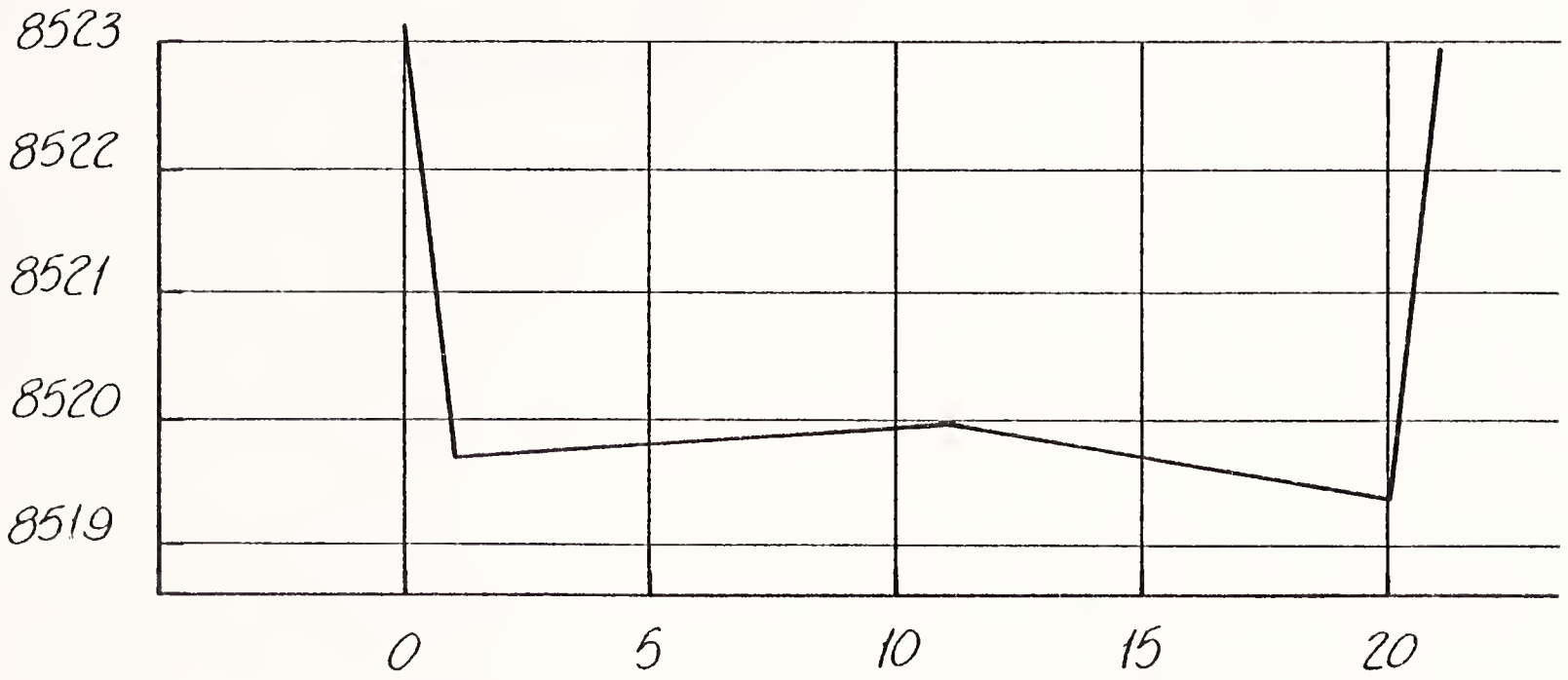
PLATE 3B

HILL RESERVOIR DAM
SPILLWAY



SPILLWAY PROFILE

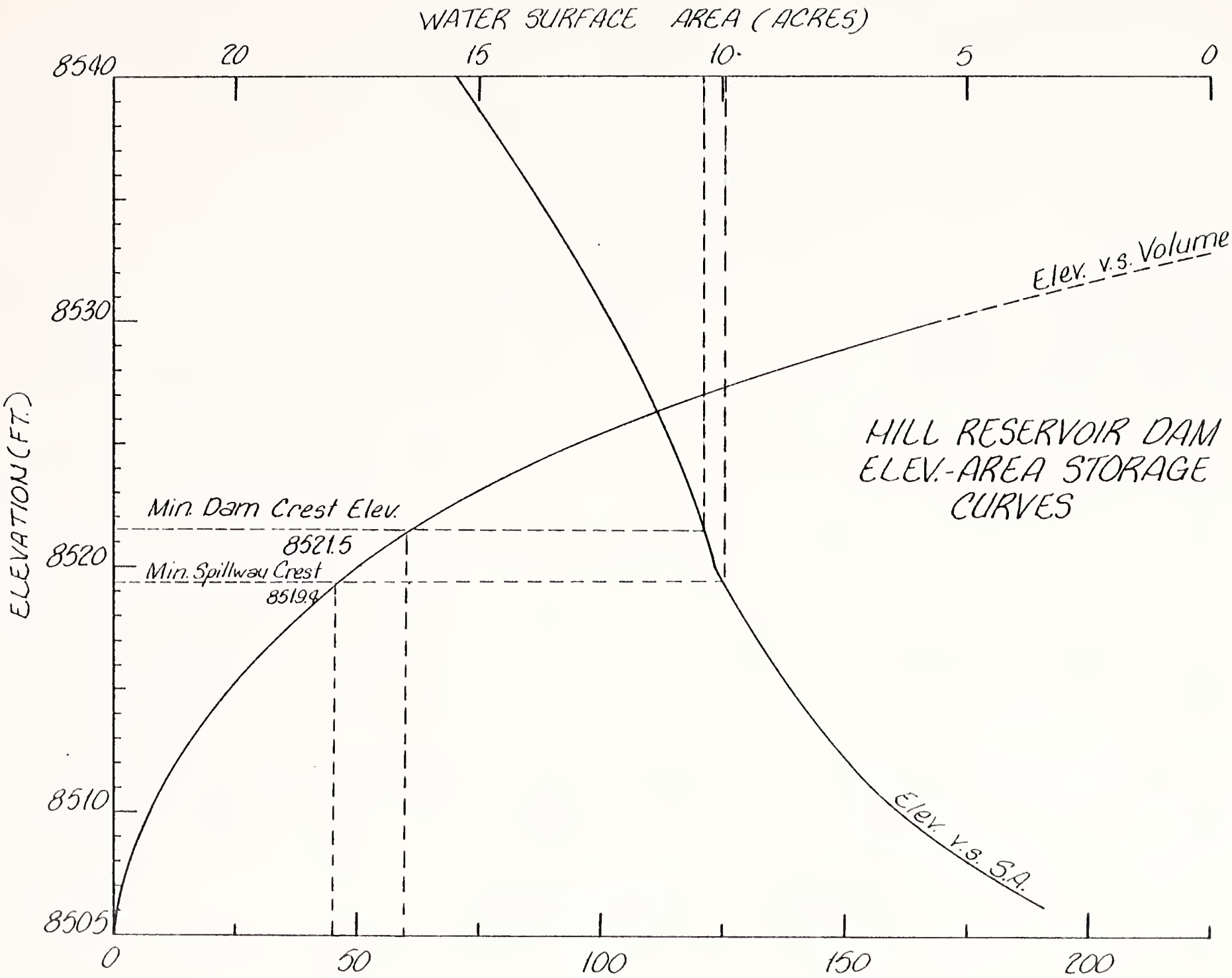
Scale: 1"=10' Horiz.; 1"= 2' Vert.



SPILLWAY CROSS SECTION AT CREST

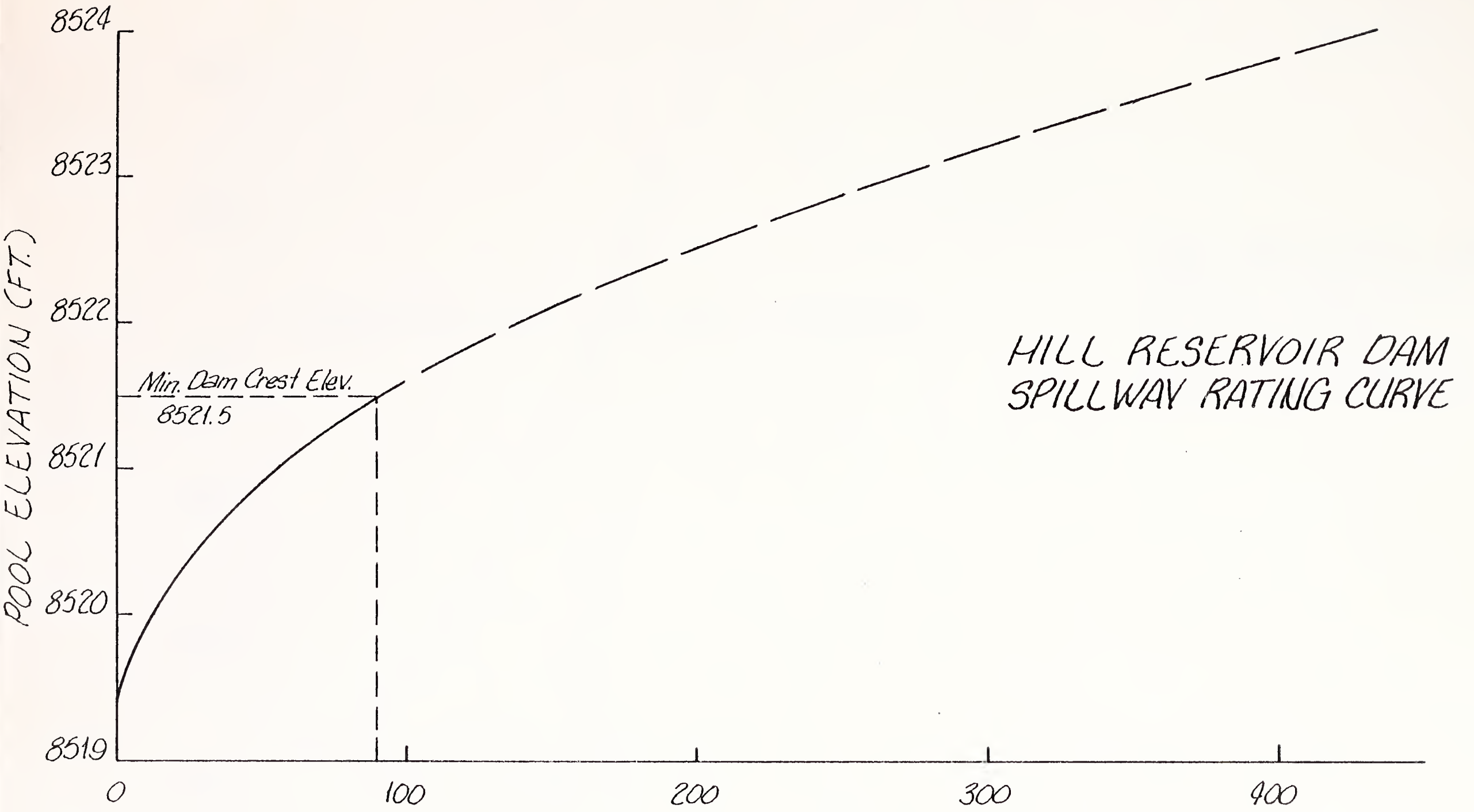
Scale: 1"=5' Horiz.; 1"=2" Vert.

PLATE 4



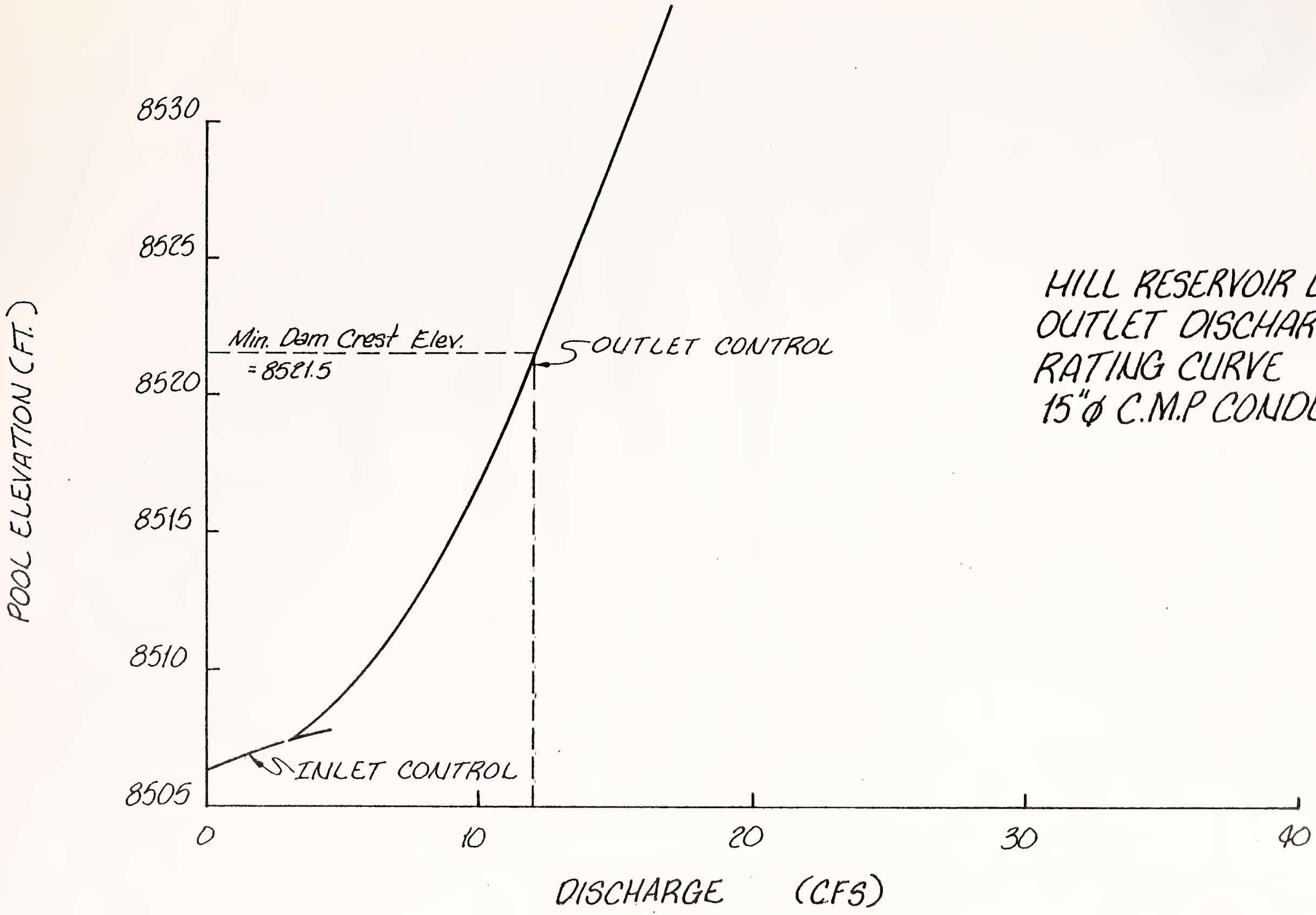
HILL RESERVOIR DAM
ELEV.-AREA STORAGE CURVES

PLATE 5



HILL RESERVOIR DAM
SPILLWAY RATING CURVE

PLATE 6



HILL RESERVOIR DAM
OUTLET DISCHARGE
RATING CURVE
15"ø C.M.P CONDUIT

PLATE 7

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

December 2, 1980

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Attn: Ralph Morrison

Re: Hoskins-Western-Sonderegger, Inc. Dam Safety Inspection Report on Hill Reservoir Dam (MT-899).

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for this opportunity to review and comment on the final draft report on the Hill Reservoir Dam.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB/AT/lj

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7530

Mr. Sidney Knutson, P.E.
Assistant Chief, Engineering Division
Corps of Engineers, Seattle District
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Knutson:

We have reviewed the draft report of the Phase I inspection for Hill Reservoir Dam and have the following comments.

The decision to restore or breach Hill Reservoir Dam has not yet been made by the permittee, the Three Creeks Water Company. In the interest of dam safety, the Forest Service has restricted storage in the reservoir until action is taken. Any plans to repair the structure will be submitted to the State of Montana and the Forest Service for review and approval.

We agree a proper hydrologic analysis and flood routing is needed to yield design requirements for restoration of the structure and believe conclusions as to the "safety" of the dam be deferred until this analysis is made.

Sincerely,

Robert W. Larse

R. W. LARSE
Director
Engineering